Developing a Biogeochemical Process-Based Model for Estimating GHG Emissions from California Dairies

(An on-going project supported by California Energy Commission Public Interest Energy Research Program)

William Salas*, Applied Geosolutions, LLC

Changsheng Li, University of New Hampshire, Durham

Frank Mitloehner, University of California, Davis

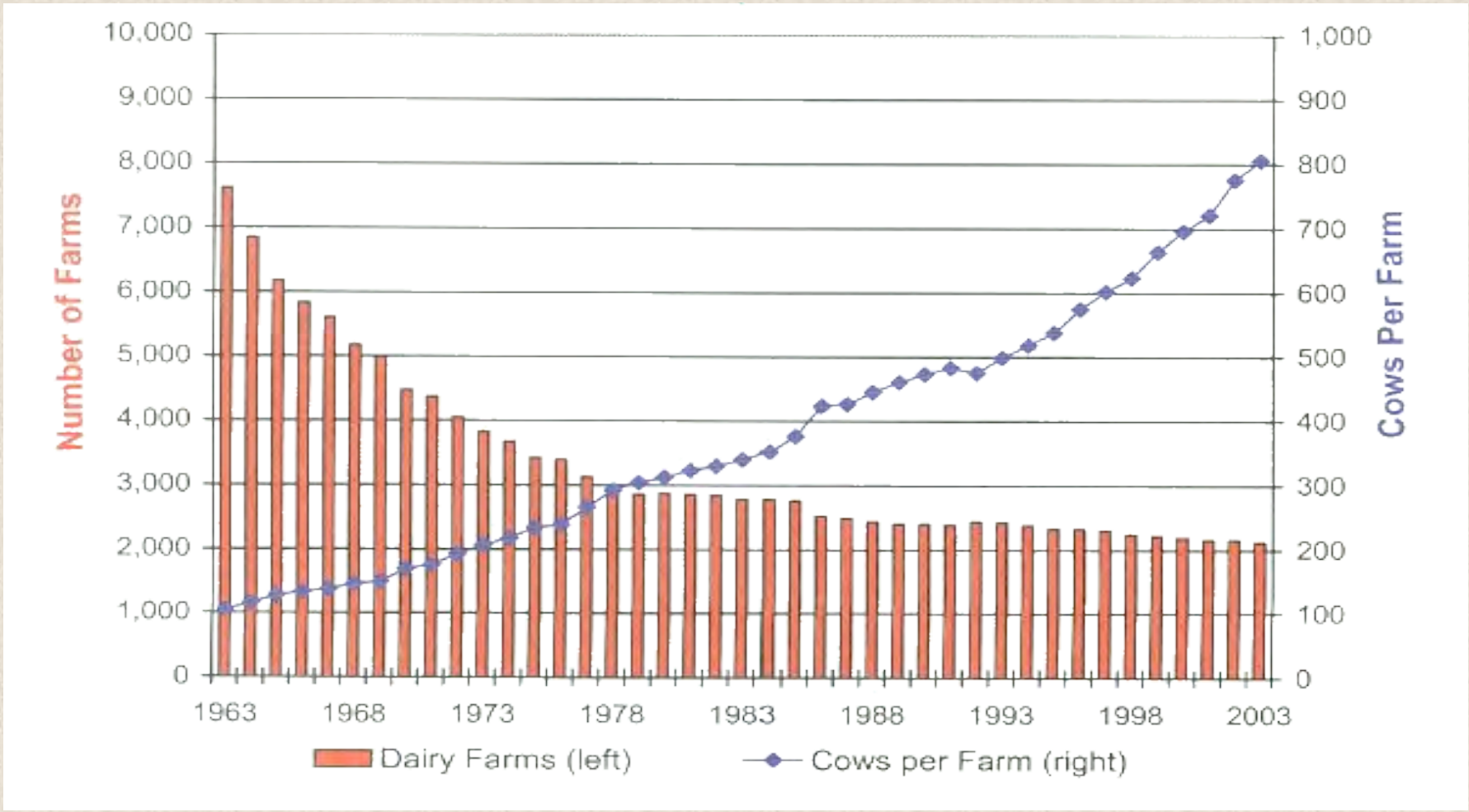
Charles Krauter, California State University, Fresno

John Pisano, University of California, Riverside

* wsalas@agsemail.com, ph: 603-292-5747

Presented at the 3rd Annual Research Conference on Climate Change, Sacramento, CA, Sept 13-15, 2006

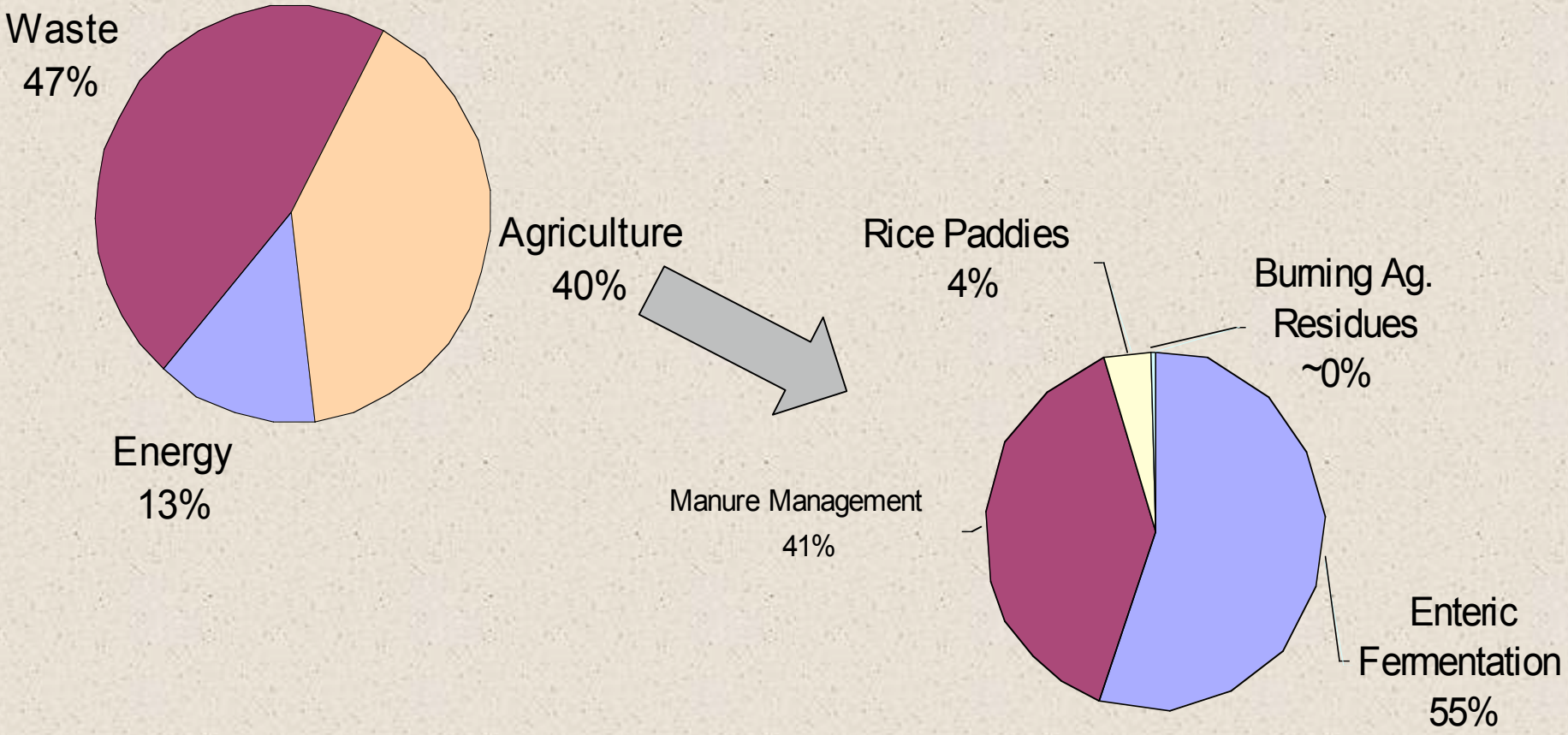
California Dairy Industry



Source: CDFA 2004

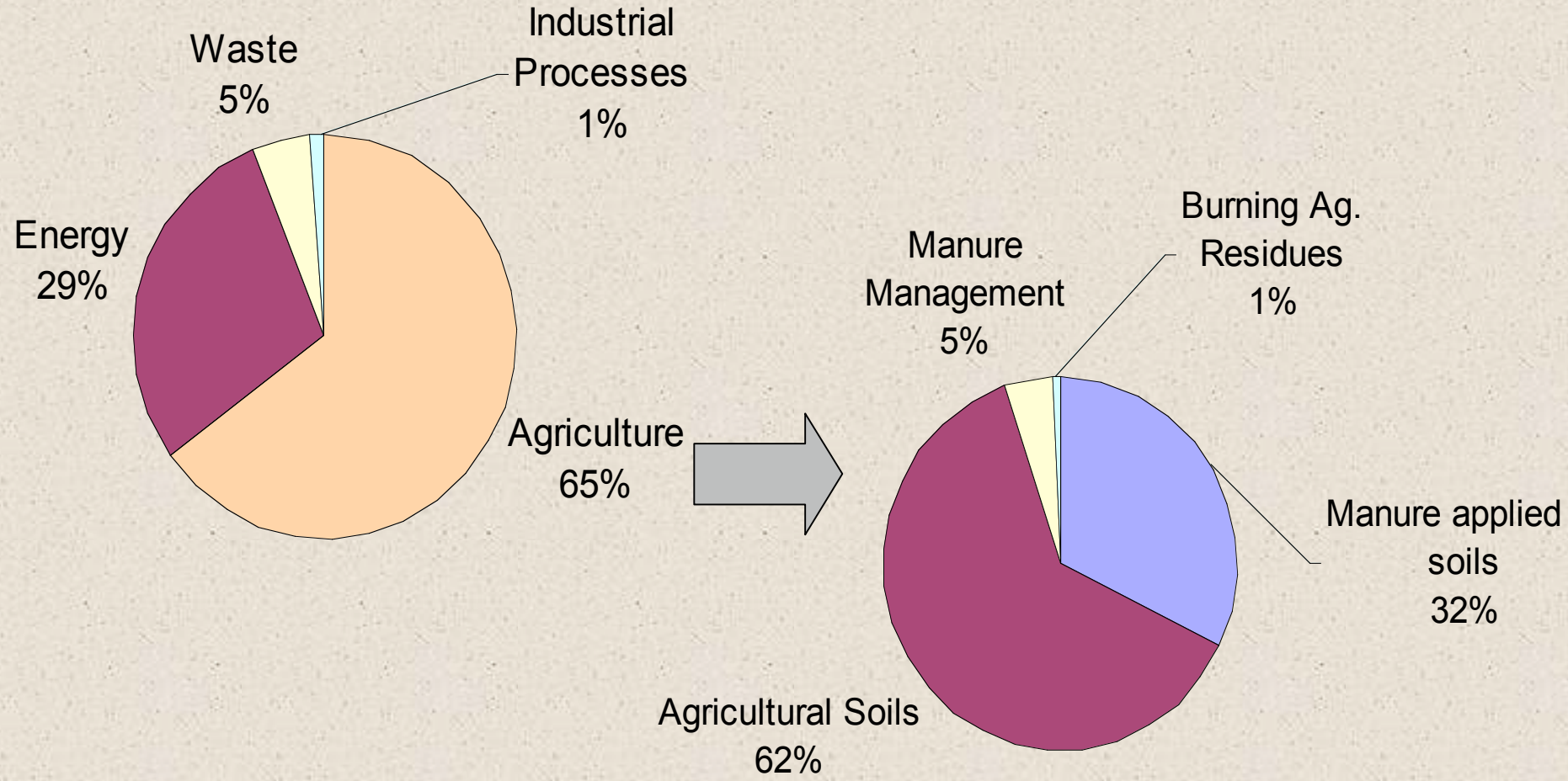
Presented at the 3rd Annual Research Conference on Climate Change, Sacramento, CA, Sept 13-15, 2006

1999 California CH_4 Emissions
31.65 $MMTCO_2eq$



Source: CEC 2002 GHG Inventory

1999 California N_2O Emissions
23.55 $MMTCO_2eq$



Source: CEC 2002 GHG Inventory

Presented at the 3rd Annual Research Conference on Climate Change, Sacramento, CA, Sept 13-15, 2006

Project Goals

- Modify an existing "process-based" biogeochemical model (DNDC) for estimating CH4, NH3, NO, N2O emissions from dairy systems in California.
- Collect field data to calibrate and validate this model (previous talk)
- Build GIS databases on soils, climate, dairy locations, and manure management.
- Apply the model to estimate emissions across California. Note: model is designed for both regional and single farm simulations.

Presented at the 3rd Annual Research Conference on Climate Change, Sacramento, CA, Sept 13-15, 2006

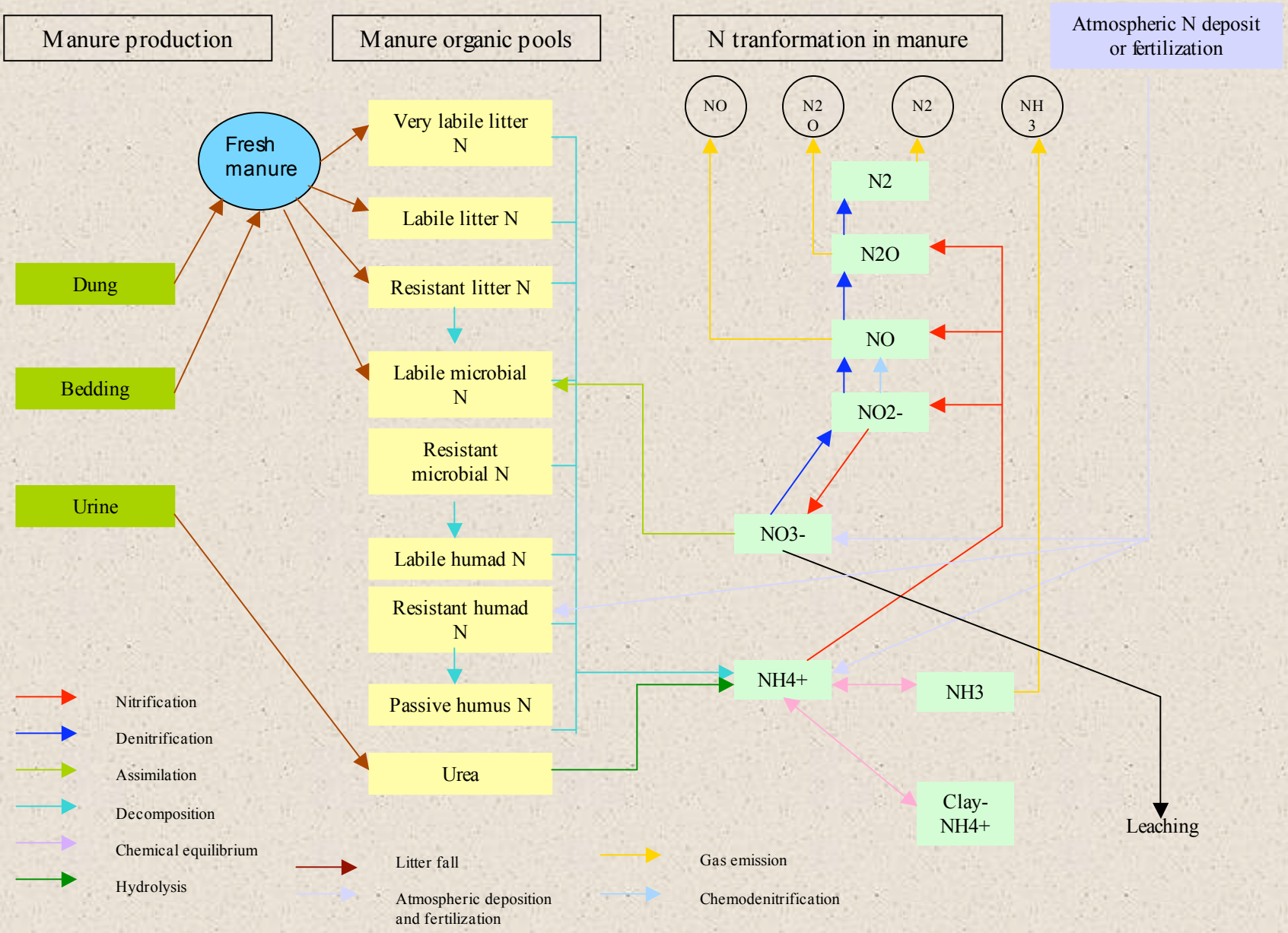
Role of Process-based Models

- Accurate assessment of air emissions from dairies with emission factors is difficult due to:
  1. high variability in the quality and quantity of animal waste, and
  2. numerous factors affecting the biogeochemical transformations of manure during collection, storage and field application.
- Measurement programs are essential but expensive and thus not feasible for monitoring and emission inventories.
- Therefore, process-based models that incorporate mass balance constraints are needed to extrapolate air emissions in both space and time (NRC, 2003).

What are Process-based Models?

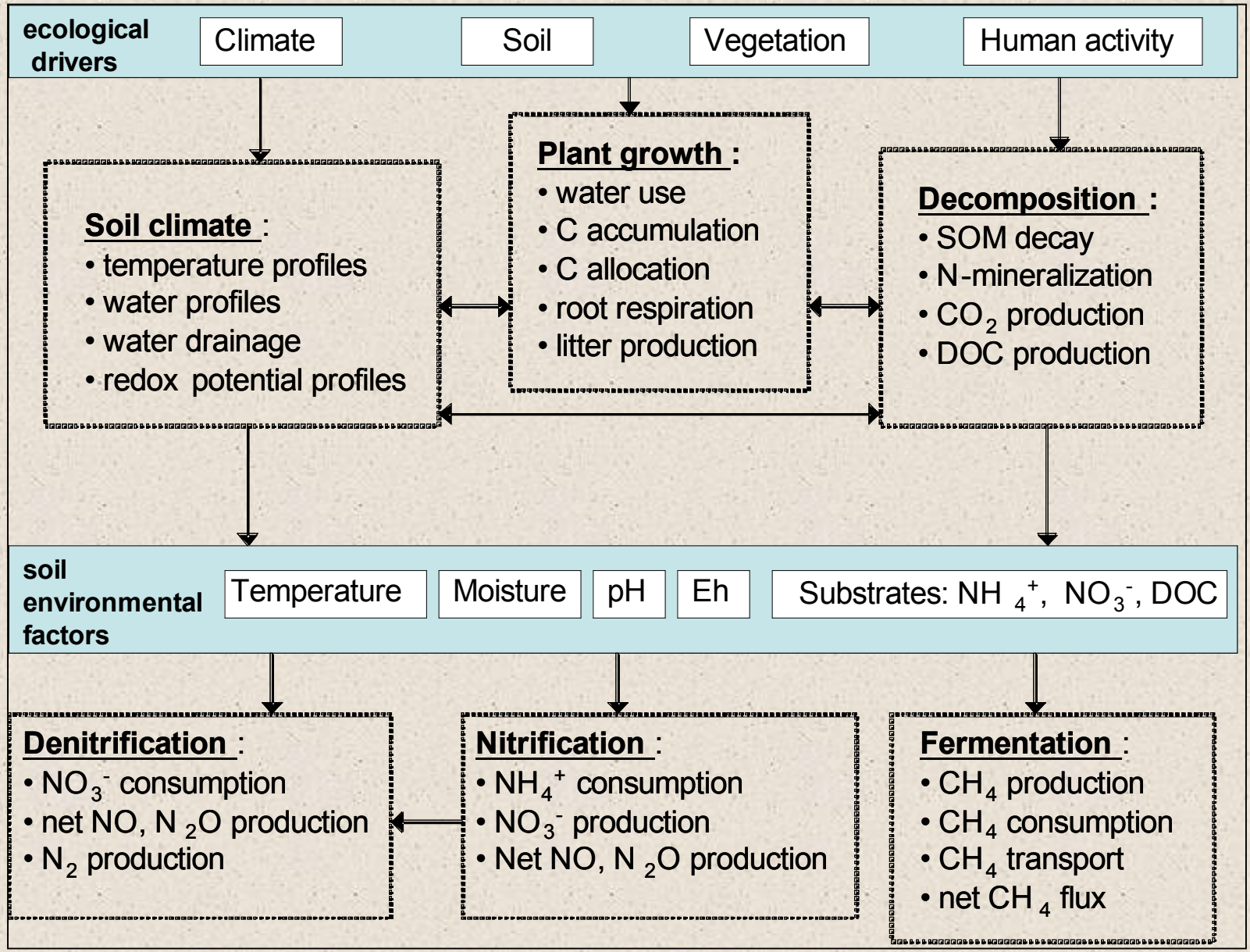
- Process-based modeling refers to biochemical and geochemical reactions or processes
  - Process modeling, in this case, does **not** refer to AFO practices or components (e.g. dairy drylots or manure lagoons) per se, but
- **Biogeochemical processes**… like decomposition, hydrolysis, nitrification, denitrification, etc…
- True process-based models **do not rely on constant emission factors**. They simulate and track the impact on emissions of varying conditions within components of the dairies (e.g., climate, flush lanes, storage facility, soils).

Nitrogen Biogeochemistry of Manure



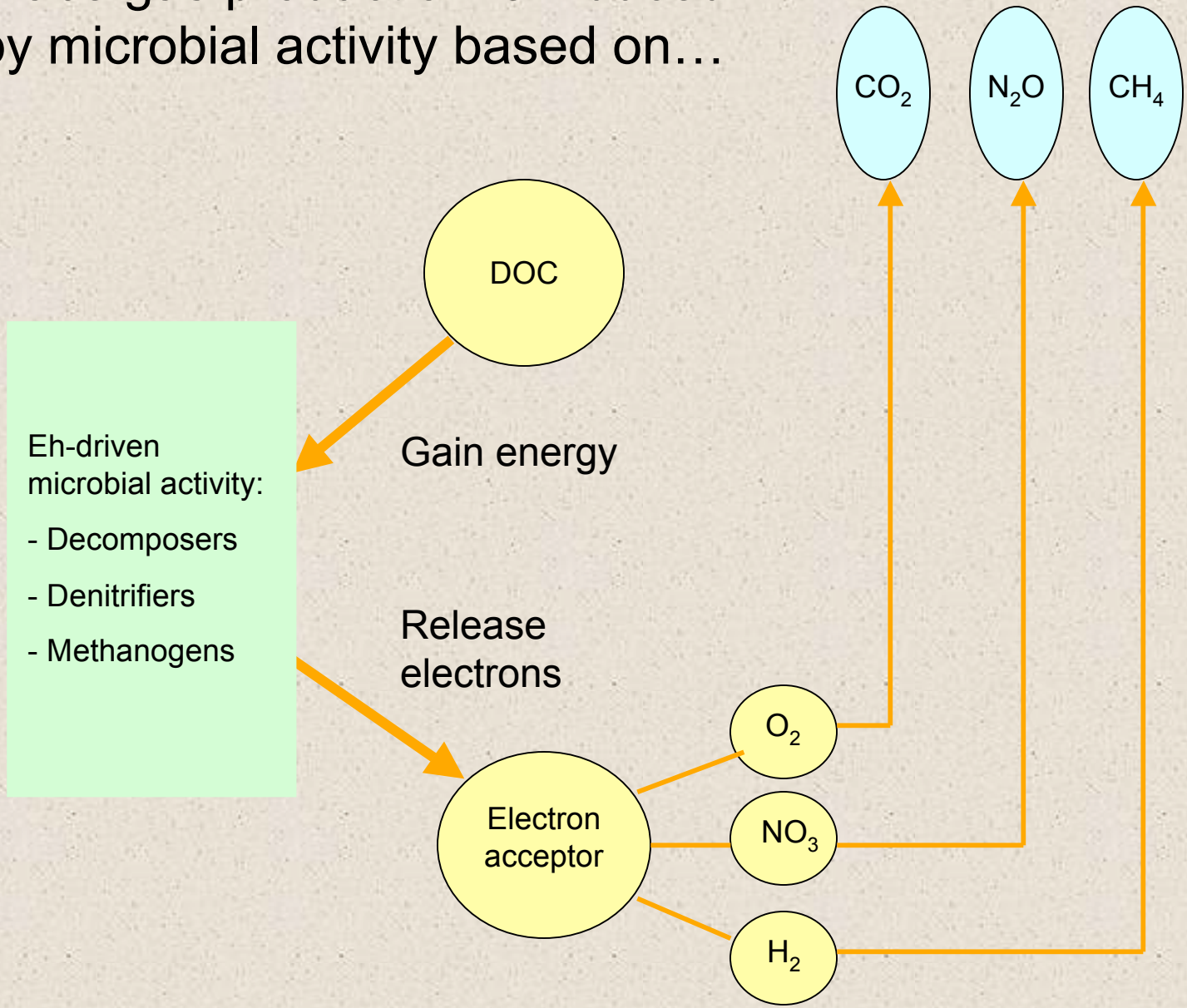
Presented at the 3rd Annual Research Conference on Climate Change, Sacramento, CA, Sept 13-15, 2006

The DNDC Model

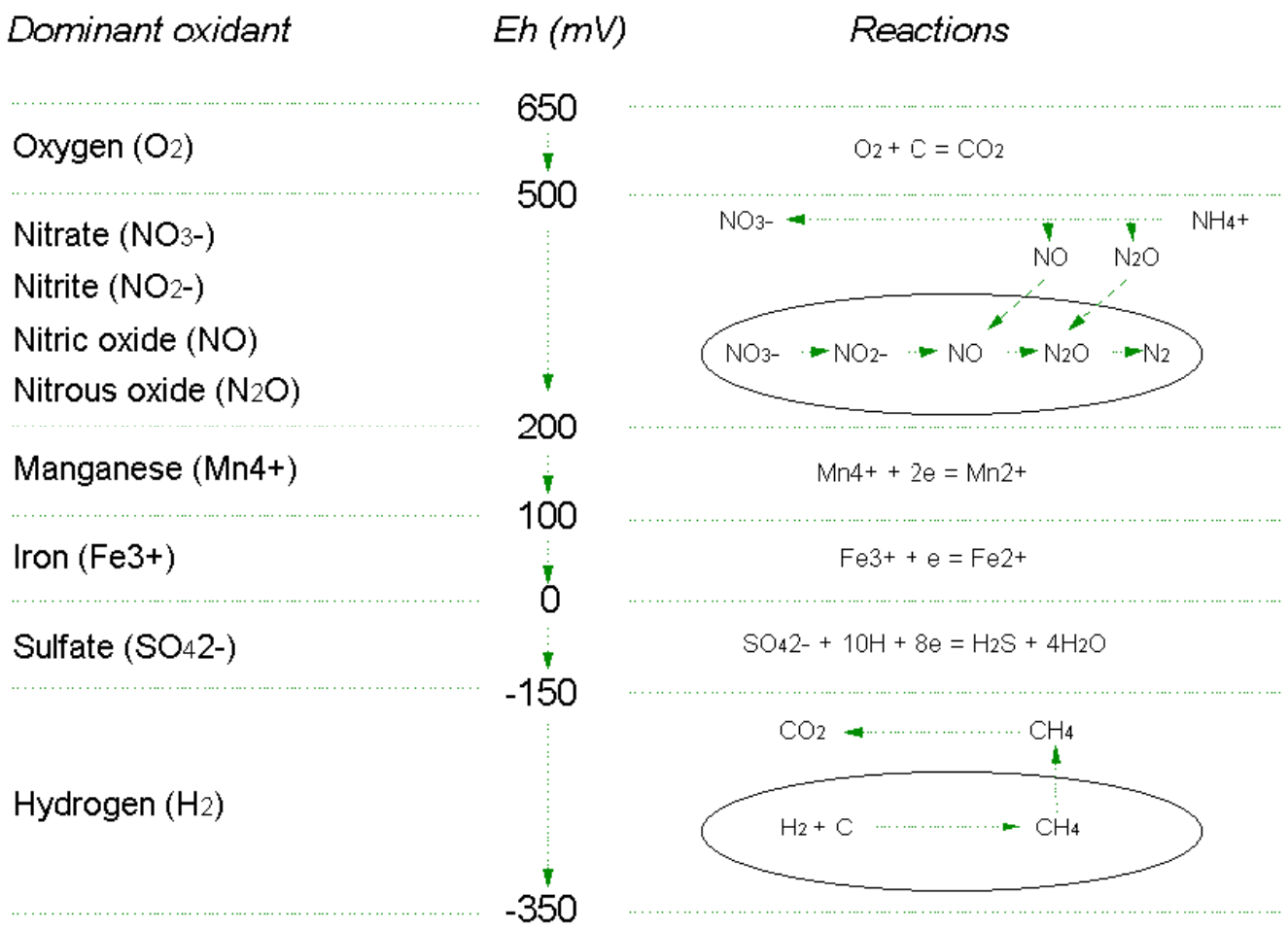


Presented at the 3rd Annual Research Conference on Climate Change, Sacramento, CA, Sept 13-15, 2006

Trace gas production is induced by microbial activity based on…



Soil CO_2, N_2O and CH_4 production is driven by the microbes demanding electron acceptors

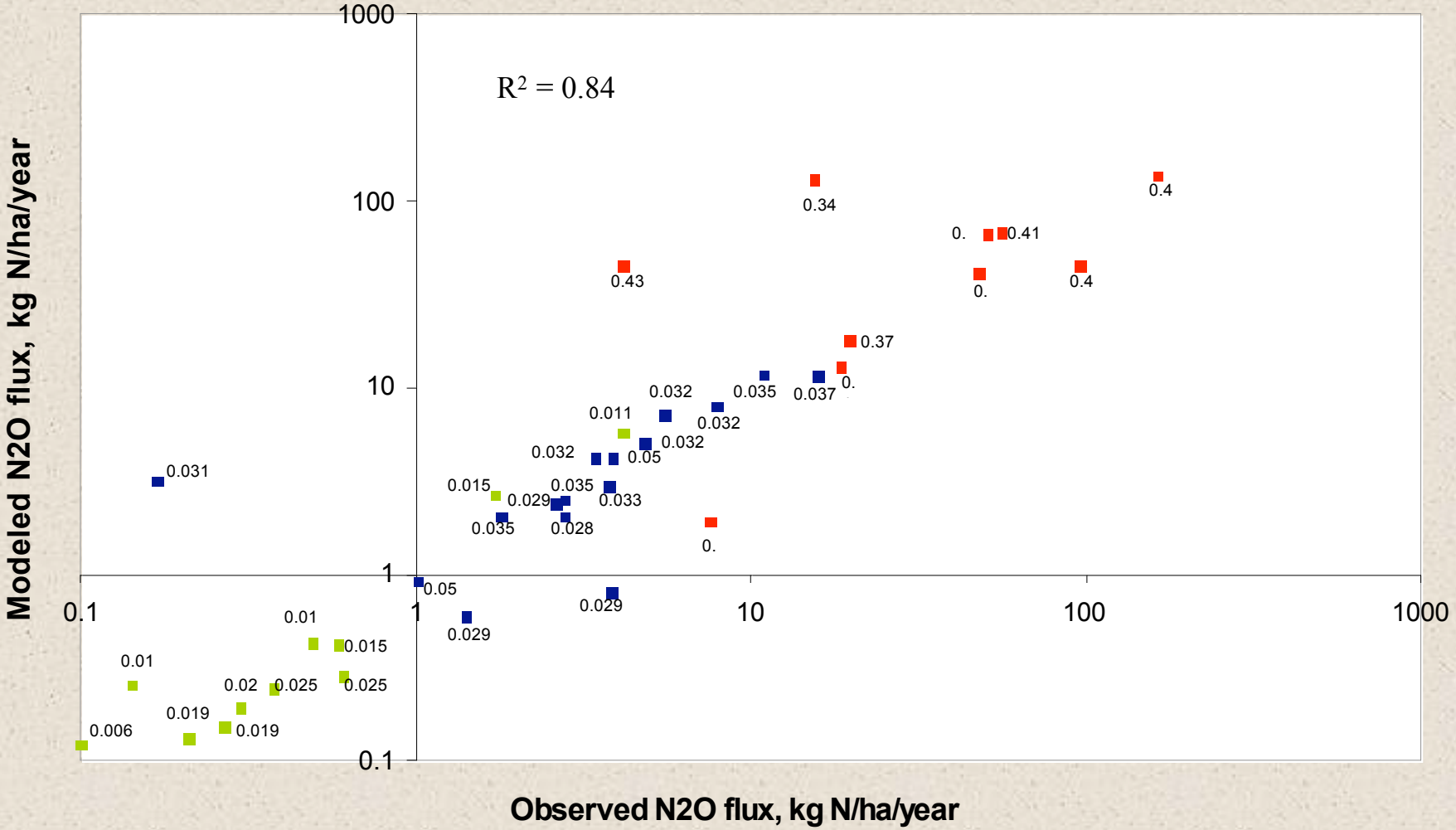


Presented at the 3rd Annual Research Conference on Climate Change, Sacramento, CA, Sept 13-15, 2006

Why DNDC Model?

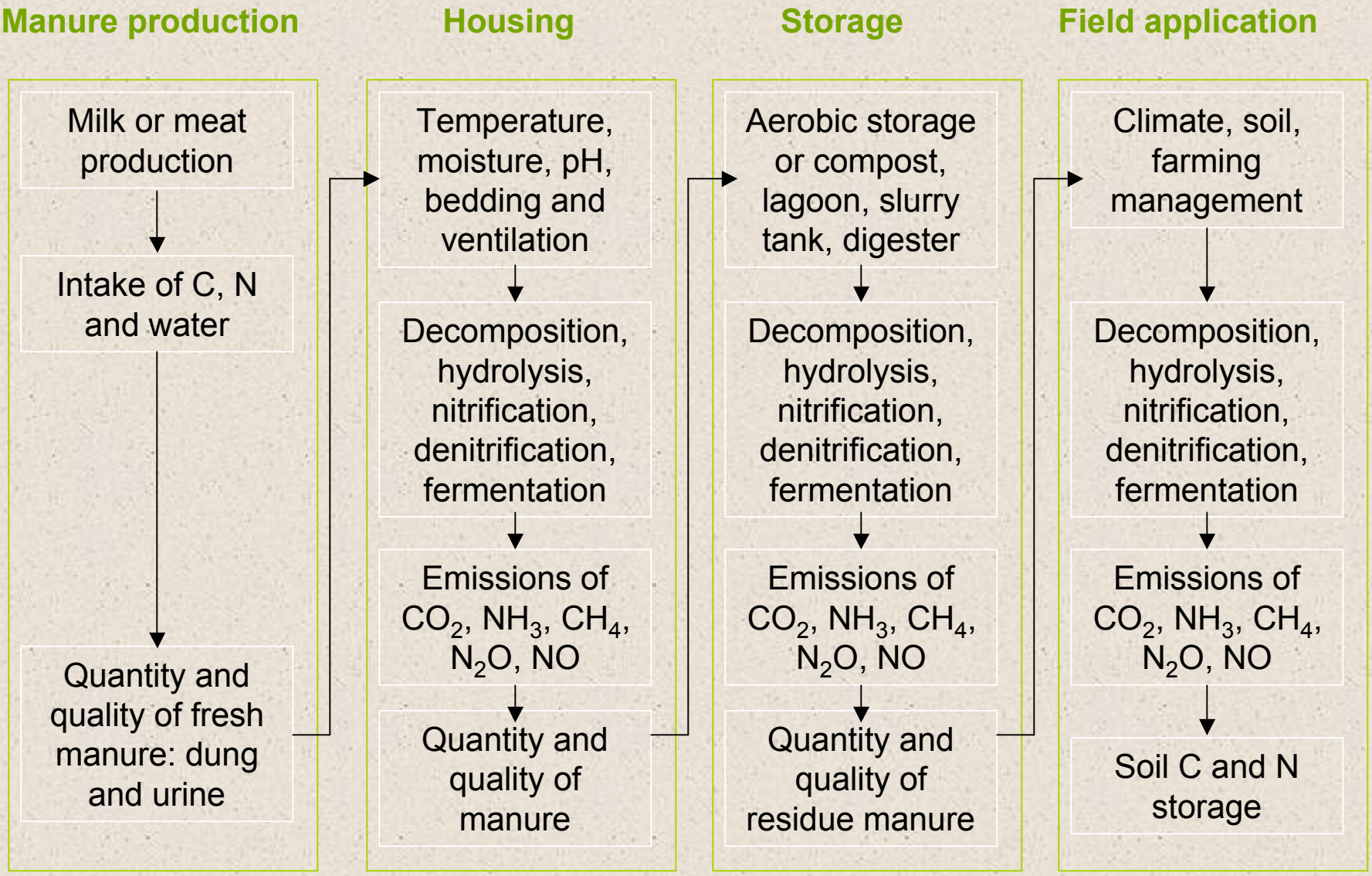
- Contains algorithms for both anaerobic and aerobic soil environments
- Simulates full range of biogeochemical processes: decomposition, hydrolysis, nitrification, denitrification, ammonium adsorption, chemical equilibriums of ammonium/ammonia, fermentation, and gas diffusion
- Well validated across a wide range of agroecosystems and is currently being used for national GHG emission inventories and mitigation studies worldwide.

Observed and DNDC-Modeled N2O Fluxes from Agricultural Soils in the U.S., Canada, the U.K., Germany, New Zealand, China, Japan, and Costa Rica



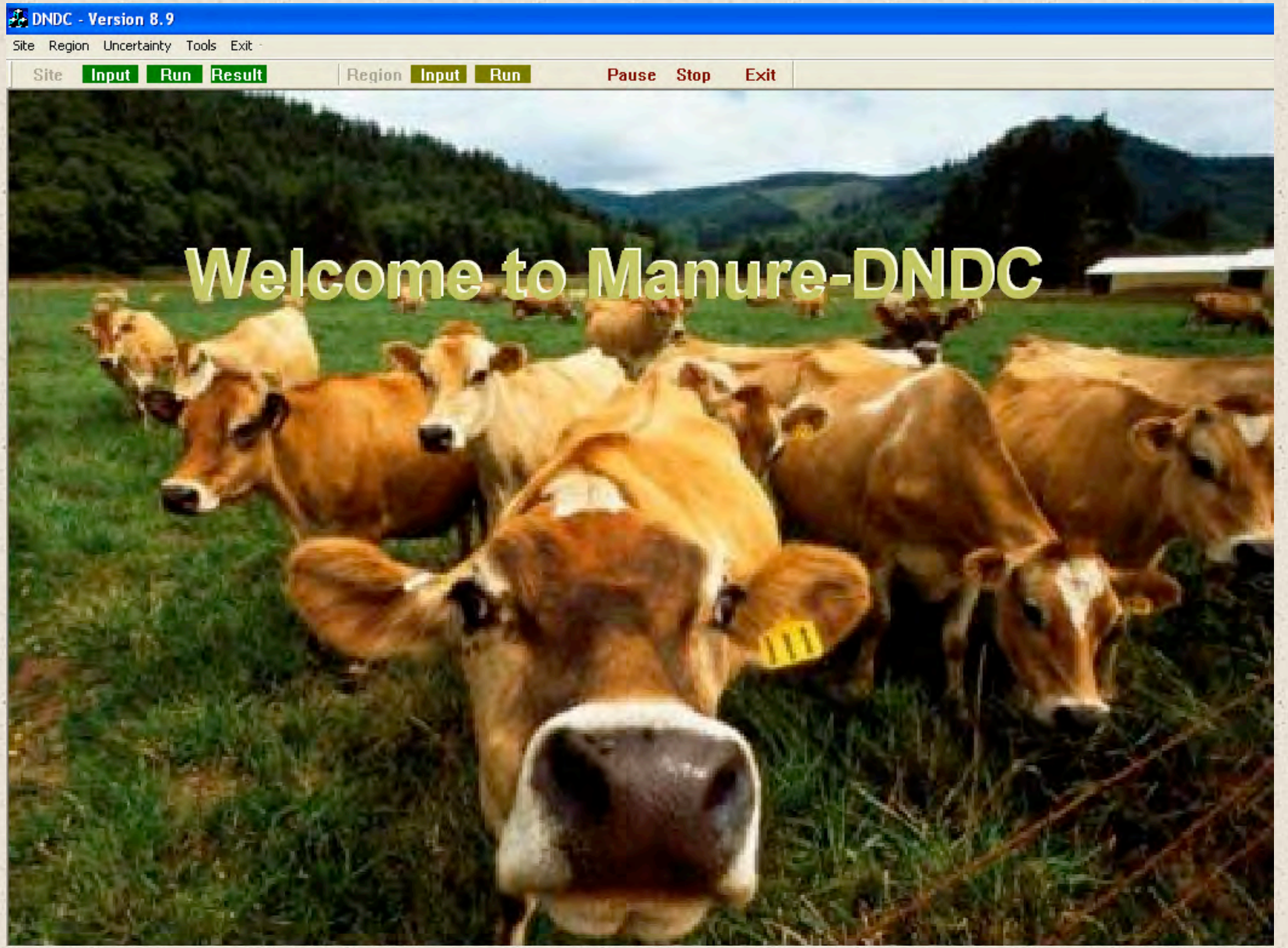
Presented at the 3rd Annual Research Conference on Climate Change, Sacramento, CA, Sept 13-15, 2006

Structure of Manure-DNDC



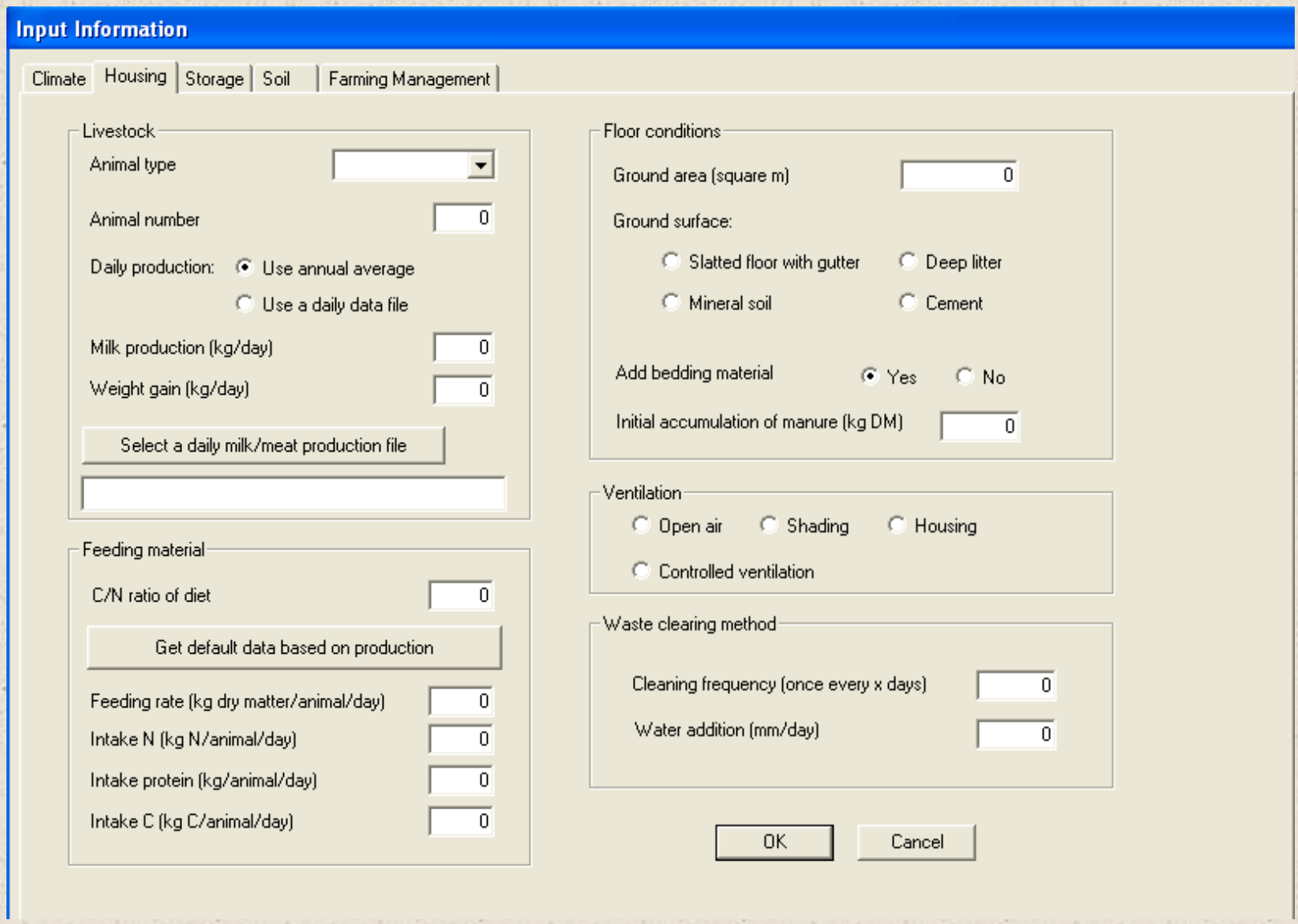
Presented at the 3rd Annual Research Conference on Climate Change, Sacramento, CA, Sept 13-15, 2006

Model Status



Presented at the 3rd Annual Research Conference on Climate Change, Sacramento, CA, Sept 13-15, 2006

Easy to Use Input Interface for Defining Climate, Housing, Storage, Processing, Soil, and Field Application Conditions



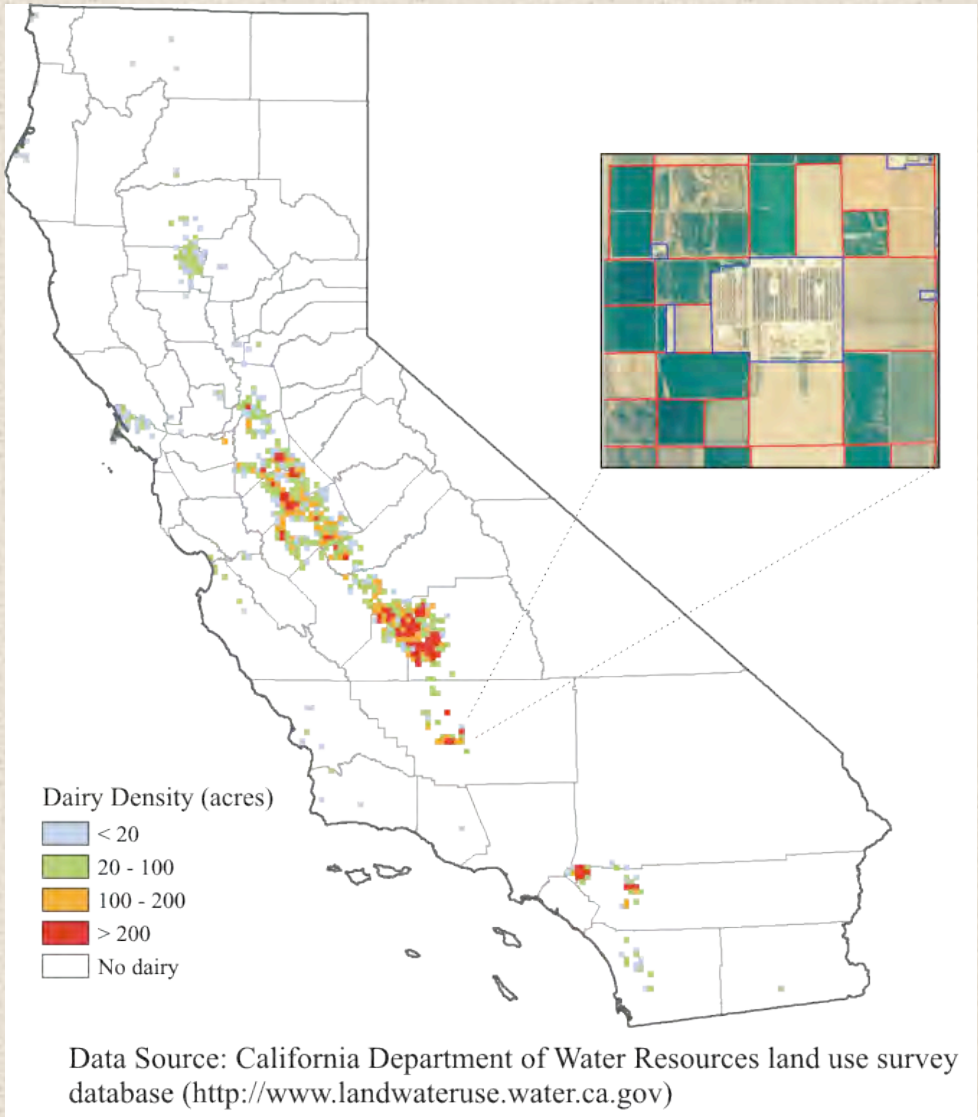
Presented at the 3rd Annual Research Conference on Climate Change, Sacramento, CA, Sept 13-15, 2006

Manure-DNDC will be validated with datasets observed in housing, storage, treatment and field application.

Sampling and measurement are conducted at feed-lot, housing, storage, lagoon and field in 3-5 dairy farms in CA in 2006-2007

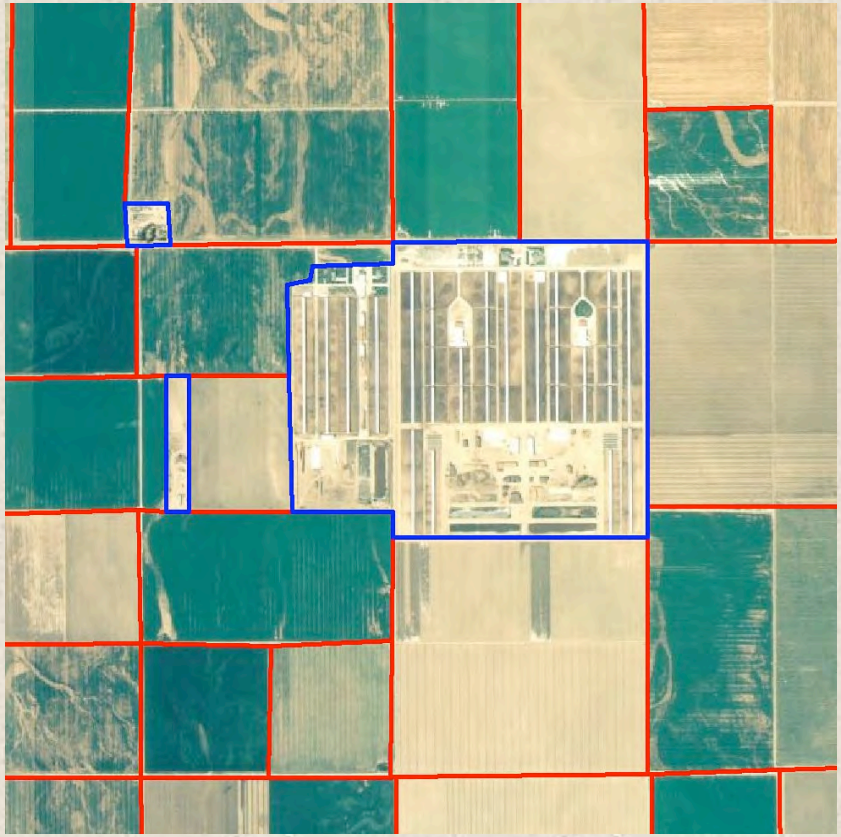
Presented at the 3rd Annual Research Conference on Climate Change, Sacramento, CA, Sept 13-15, 2006

GIS databases have been constructed to support regional simulations for CA dairies



Data Source: California Department of Water Resources land use survey database (http://www.landwateruse.water.ca.gov)

Climate, soil, livestock and management information have been collected.

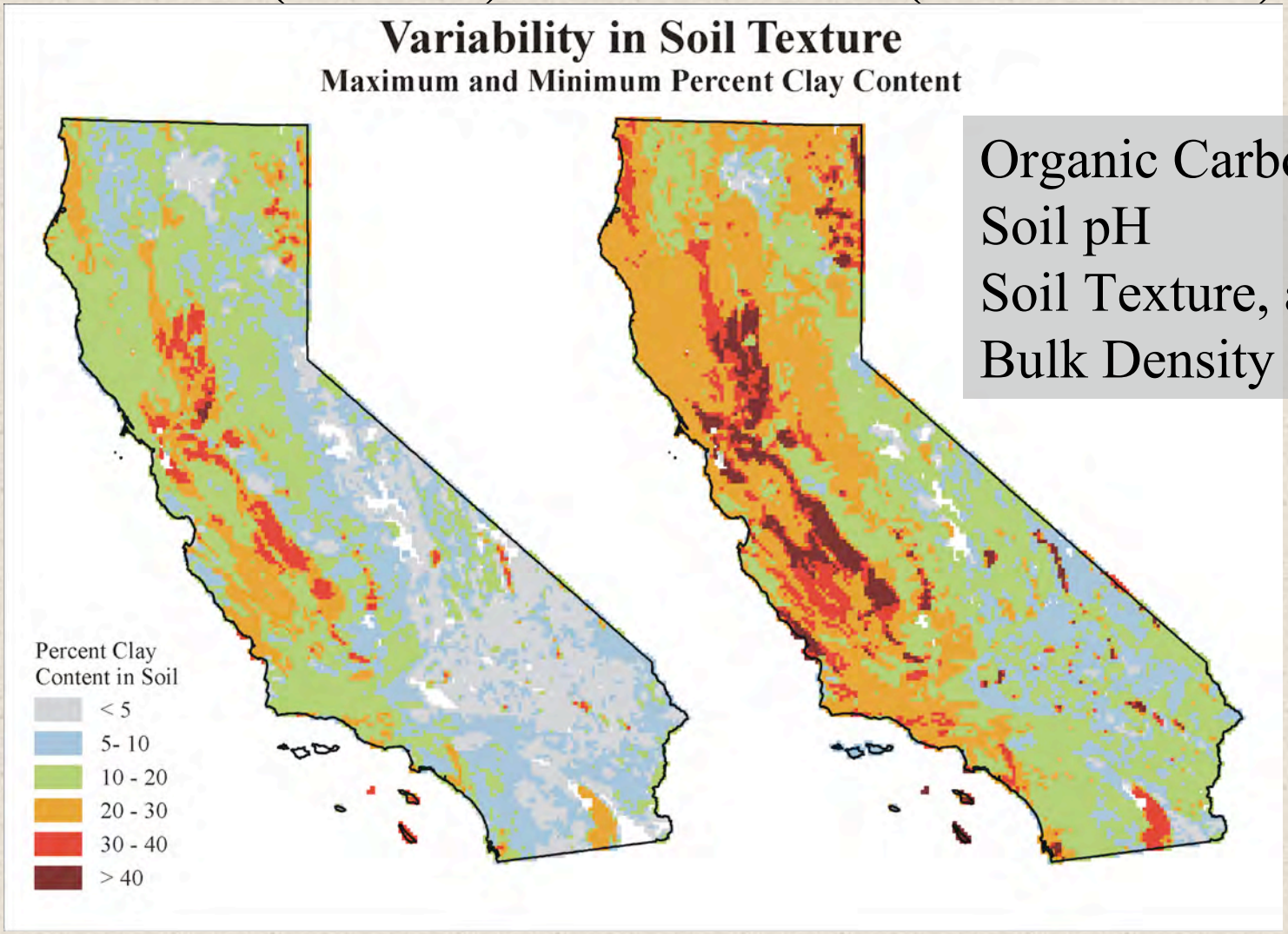


Environmental Factors: Climate Data

- DAYMET: Gridded (1kmx1km) daily min/max T, precipitation, relative humidity, and solar radiation. Available from 1980.
- CIMIS (California Irrigation Management Information System): station data with hourly Temp, Precip, Radiation, Rel Hum, Wind Speed, …).
- Built automated routines for data mining, QA/QC and pre-processing into Manure-DNDC format.

GIS Soils: NRCS Soil Surveys

- STATSGO (1:250K) and SSURGO (1:12k-1:63K)



Organic Carbon
Soil pH
Soil Texture, and
Bulk Density

Presented at the 3rd Annual Research Conference on Climate Change, Sacramento, CA, Sept 13-15, 2006

Expected Project Outcomes:

- Biogeochemical process modeling tool for estimating air emissions (CH_4, NH_3, N_2O, NO) and N leaching from California dairies;
- GIS databases on dairies (location, types, herd sizes, manure management, local soils, climate, etc);
- Regional estimates of NH_3 and GHG emissions from California dairies;
- Emission inventory tool for emission inventories ranging from project or facility level up to air-district and state level

Thank you!